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Review article

Sarcopenia in Asia

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Abstract

Sarcopenia is a progressive and generalized loss of muscle mass and either a loss of muscle strength or physical performance. Its prevalence increases with age and is associated with multiple unfavorable clinical outcomes. The operational definitions and diagnostic strategy of sarcopenia in Asia is currently based on the consensus of the Asian Working Group of Sarcopenia (AWGS) which requires measurements of muscle mass, muscle strength, and physical performance. This article reviewed the epidemiology, impact, pathophysiology, recommended tools and their cut-offs for diagnosis of sarcopenia in Asia according to the consensus of the AWGS and existing evidence in Asia. It is clear that exercise, diet and nutrition are beneficial for sarcopenic adults in the areas of prevention and treatment but no medications are currently proven. Future study in Asia should be straight forward to include intervention for prevention and treatment of sarcopenia.

Keywords: Definition; Diagnosis; Epidemiology; Frailty; Sarcopenia

1. Introduction

Sarcopenia, a new geriatric syndrome, is an aging-related condition defined by a progressive and generalized loss of muscle mass and function defined as muscle strength and/or physical performance [1,2]. Sarcopenia has emerged as one of the most common problems in the elderly population and is representative of one of the most significant public health concerns since it can accelerate to the frailty syndrome [3] resulting in adverse clinical outcomes and health status, i.e., physical impairment and disability, poorer quality of life, increased risk of falls, hospitalization, morbidity, mortality and health care costs [4–10].

Over the past two decades after the term "sarcopenia" was introduced by Rosenburg [11], the research in sarcopenia has been investigated extensively including pathophysiology, risk factors, criteria for diagnosis, consequences of sarcopenia and therapeutic options. Due to the escalation of the elderly population worldwide and especially in Asia, the importance of prevention and early detection of individuals with sarcopenia is crucial.

2. Epidemiology of sarcopenia in Asia

In general, a progressive loss of muscle mass occurs at the age of 40 at the rate of 8% per decade and increases to 15% per decade after 70 years [12]. For muscle strength, it declines 10–15% per decade and more rapidly after the age of 70 years [12]. A longitudinal study of muscle mass, grip strength and gait speed change over 4 years in a community setting of older Chinese showed that these older Chinese had less muscle mass, weaker grip strength and slower gait speed than black or white people of the same age. The decline of gait speed and grip strength was faster than muscle mass but the decrease of grip strength in Chinese women was especially notable [13]. The prevalence of sarcopenia in Asia was different among

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countries, ages of studied populations, gender, settings of populations and measurement methods. There is inconsistent prevalence of sarcopenia in Asian populations [3,12,14]. The prevalence; however, was higher with advancing age and higher in men than in women in most studies. Additionally, persons with a low body mass index and who lived in nursing homes had a higher prevalence of sarcopenia [15]. The studies in older Chinese communities found that being under weight, advancing age, cigarette smoking, chronic obstructive pulmonary disease (COPD), atherosclerosis and physical inactivity were associated with sarcopenia [16,17] whereas the one study in Thailand showed that apart from advancing age, an urban environment and high body mass index were the predictive factors for sarcopenia [18].

The studies regarding sarcopenia in Asia are fewer than the studies in Europe and America. Existing Asian studies were conducted in Japan, China, Taiwan, Korea and Thailand. The prevalence of sarcopenia based on low muscle mass alone is greater than the current definition which required either low muscle strength or poor physical performance. Asian people appear to have a higher prevalence of sarcopenia than other regions [15]. Its prevalence in older adults according to low muscle mass in Asia varied from 6.7 to 56.7% in men and 0.1−33.6% in women [14,16] whereas the prevalence according to the current definition is 9.6−22.1% in men and 7.7−21.8% in women [14,15]. The prevalence of sarcopenia using only low muscle mass in diabetic patients in the Korean Sarcopenic Obesity Study (KSOS) was 15.7% and found that diabetes was an independent factor associated with sarcopenia [19]. Setting uniform criteria among Asian countries and using optimal cutoff points for individual ethnicities would be worthwhile for further studies regarding the impact and appropriate management of sarcopenia.

3. Impact of sarcopenia

The impacts of sarcopenia are the results of intrinsic causes; physiologic change of ageing and extrinsic causes that lead to increased metabolic demands such as chronic illness, lifestyle behavior and medication use. Consequently, physical inactivity occurs and accelerates frailty. Several public health burdens are evidenced accordingly including physical disability, falling, nursing home admission, hospitalization, depression, poor quality of life, increased health care expenditures, poor physical performance, adverse metabolic effects and even mortality [12,14,20].

Sarcopenic patients had a worse functional status than non-sarcopenic patients. One report showed that older patients from subacute geriatric wards with sarcopenia had a negative impact on their functional status during hospitalization and even at 3-month follow-ups than the patients without sarcopenia [21]. It indicates the impairment in activities of daily living, gait speed or regularity [15]. A study in older Japanese showed that the prevalence of sarcopenia was greater in persons who had a history of falling with the odds ratio of 4.42 (95%CI 2.08−9.39) in men and 2.34 (95%CI 1.39−3.94) in women [22]. A prospective study in sarcopenic older adults aged 80 years or over showed an increased mortality independent of age and other clinical and functional variables with the hazard ratios (HR) of 2.32, 95%CI: 1.01−5.43 [23].

Additionally, sarcopenia is associated with several comorbidities including osteoporosis and possibly increases fracture risk via crosstalk between muscle and bone tissues and escalates the falling risk [15]. The presence of atherosclerotic-related diseases such as hypertension, diabetes, cardiovascular disease (CVD), chronic kidney disease is also associated with sarcopenia particularly in patients with sarcopenic obesity [15,24−26]. Japanese studies also found that the association between sarcopenia and cardiovascular disease was not dependent on the waist circumference, age and body composition [26,27]. One study in Korea reported that the women with sarcopenic obesity and even sarcopenia without obesity had three times and twice the risks of developing metabolic syndrome than normal subjects. The similar trend was also found in men [28,29].Arterial stiffness, especially in the female, is associated with sarcopenia as shown in Korean and Japanese studies [25,26]. The possible mechanisms are insulin resistance since muscle loss causes a reduced insulin-responsive target tissue, inflammatory processes, reduced myokines and a change in the renin-angiotensin-aldosterone system (RAAS) that may promote CVD risks and a derangement of other metabolic profiles [24,25]. Furthermore, hypogonadism and hypercortisolism is also associated with sarcopenia independent of age under the mechanism of physical disability [15].

4. Pathophysiology

There are several proposed mechanisms of sarcopenia that can be classified as primary or age-related sarcopenia. It is associated with sex hormones, apoptosis and mitochondrial dysfunction, anorexia of ageing, and secondary sarcopenia including 1) neurodegenerative processes such as motor neuron diseases, 2) endocrinopathy which is associated with a reduction of anabolic hormone levels, eg. growth hormone, insulin like growth factor-1 (IGF-1), testosterone, vitamin D, increased cortisol, abnormal thyroid function and insulin resistance, 3) pro-inflammatory cytokines that are interleukin-1, interleukin-6 and tumor necrosis factor-alpha, 4) inadequate nutrition or malabsorption and 5) disuse situations such as the immobilization syndrome, physical inactivity and persons with zero gravity [3,12,30,31] (Fig. 1).

5. Definition

Currently, operational definitions and diagnostic strategy of sarcopenia in Asia is based on the consensus of the Asian Working Group of Sarcopenia (AWGS) which was modified from the European Union Geriatric Medicine Society (EUGMS) and the European Working Group on Sarcopenia in Older People (EWGSOP). The diagnosis requires measurements of muscle mass, muscle strength, and physical performance. It is; however, different in measurement of both muscle strength and physical performance as the screening

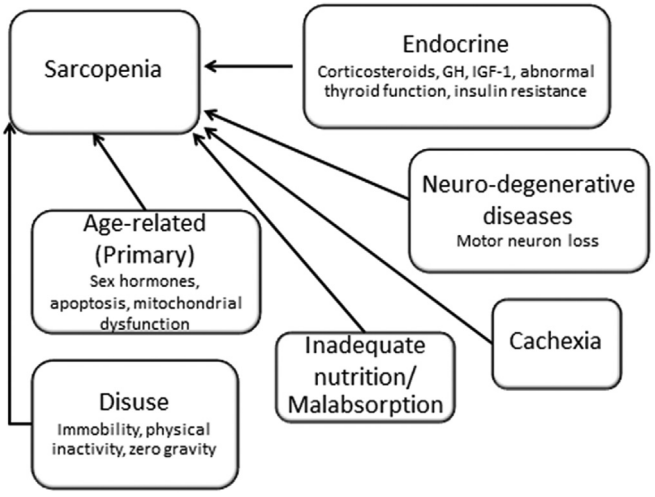

Fig. 1. Summary of pathogenesis of sarcopenia [30]. GH: growth hormone, IGF-1: insulin like growth factor-1.

tests and using different cutoff values of each parameter based on the existing studies in Asian societies. Ethnicities, body sizes, lifestyle, and cultural background can influence the different cutoff values [4,14,32]. Severities of sarcopenia are classified into 3 groups for targeted plans of management; presarcopenia, sarcopenia and severe sarcopenia. Presarcopenia is defined as a presence of low muscle mass only, sarcopenia is diagnosed when there is a presence of low muscle mass and either low muscle strength or low physical performance, and severe sarcopenia is defined as when presenting low muscle mass, low muscle strength and low physical performance are apparent [30].

There are several assessment tools to measure muscle mass, muscle strength and physical performance. Tools that used to measure muscle mass are 1) body imaging techniques; computerized tomography (CT scan), magnetic resonance tomography (MRI), and dual energy X-ray absorptiometry (DXA), 2) bioimpedance analysis (BIA), 3) potassium per fat-free soft tissue measurement, and 4) anthropometric measures. The commonly used and feasible tools are DXA and BIA. Muscle strength measurement includes handgrip strength (HS), knee flexion/extension (quadriceps strength), and peak expiratory flow (PEF). Physical Performance Battery (SPPB), usual gait speed, timed get-up-and-go test (TGUG), and Stair climb power test (SCPT) are measurement tools of physical performance. There are; however, some limitations of those tools in clinical practice including the availability, feasibility, cost, and optimal cutoff values. Recommended tools and their cutoff values in Asia according to the consensus of the AWGS and existing evidence in Asia are shown in Table 1 [14,20,30,32–34].

According to the recommendation of the AWGS [14], all older adults at the age of 60 or 65 or over, depending on definition of older adults in each country, in the community setting should be screened for sarcopenia. Case findings should be performed in at-risk persons including 1) presence of recent functional decline or functional impairment, 2) unintentional body weight loss over 5% in a month, 3) depressive mood or cognitive impairment, 5) repeated falls, 6) undernutrition, and 7) chronic conditions such as chronic heart failure, chronic obstructive pulmonary disease, diabetes mellitus, chronic kidney disease, connective tissue disease, tuberculosis infection, and other chronic wasting conditions. The algorithm of sarcopenia diagnosis presented by AWGS is demonstrated in Fig. 2 [14].

6. Management

It is clear that non-pharmacological management is beneficial for sarcopenic adults in the areas of prevention and treatment i.e. exercise, diet and nutrition. No medications are currently proven to be as efficacious as exercise but they might reduce functional decline in older adults in deficiencies such as testosterone, dehydroepiandrosterone (DHEA), growth hormone (GH) and vitamin D [3,15,20,35–37].

1 *Exercise*: physical inactivity is part of the mechanisms of sarcopenia. Therefore, exercise can reverse or prevent the occurrence of sarcopenia. Exercise appears to be the most effective method to improve quality of life and function in older adults even in the very elderly or frail adults [38]. Resistance exercise (RE) is the type of exercise that mainly increases muscle mass and muscle strength by directing stimulation of protein synthesis particularly by progressive resistance exercise (PRE) which is the most common use of resistance therapy. It requires muscle to generate power to move or resist weight and escalate the intensity when physical capacity improves [31,38,39]. A meta-analysis and systematic review showed that PRE could reduce physical disability in older adults [36,40]. Aerobic exercise is type of exercise that benefits improved cardiovascular fitness and increased endurance. It increases the cross-sectional area of muscle fibers, mitochondrial volume and enzyme activity; however, it is less likely to increase muscle hypertrophy [38,41]. Combinations of aerobic and resistance exercise can further improve muscle strength and muscle function and is important to prevent and treat sarcopenia [38,41,42].
2 *Diet*: anorexia of ageing is the commonly used word to define reduced appetite and low intake in the elderly.

Table 1
Measurement tools and recommend cutoff values in clinical practice.

Measurement	Tools	Cutoff values	
		Men	Women
Muscle mass[a]	Dual energy X-ray absorptiometry; DXA	7 kg/m^2	5.4 kg/m^2
	Bioimpedance analysis (BIA)	7 kg/m^2	5.7 kg/m^2
Muscle strength	Handgrip strength (HS)	26 kg	18 kg
	Knee flexion/extension (quadriceps strength)	18 kg	16 kg
Physical performance	6-m usual gait speed	0.8 m/s	0.8 m/s

[a] Relative appendicular skeletal mass/height [2,14].

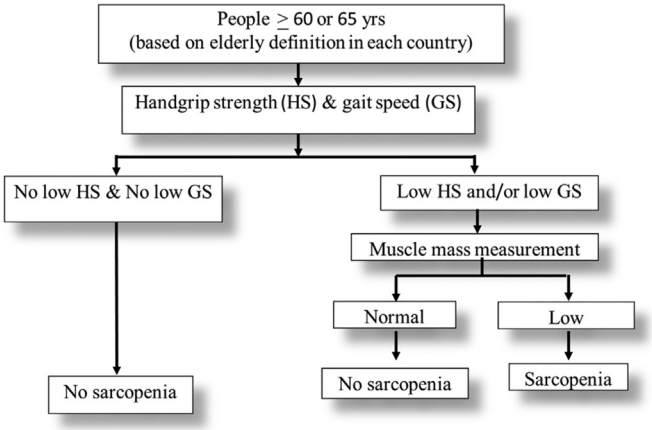

Fig. 2. Algorithm of sarcopenia diagnosis presented by AWGS. AWGS: Asian Working Group of Sarcopenia.

Inadequate protein intake is particularly the key component of established sarcopenia. Older adults usually intake less protein than the daily recommendation [12,35]. It can be the result of physiologic change, economic limitation and comorbidities. Furthermore, anabolic resistance occurs in the elderly due to the decline in insulin-like growth factor-I (IGF-I) levels in older adults relative to young adults causing blunting of the response of muscle protein synthesis [12,35]. Therefore, the daily recommendation of protein in older adults, if no contraindication is present, is about 1.5 g/kg/day which is higher than current recommended dietary allowance (RDA) of protein and should distribute protein intake throughout the day [35,38]. The essential amino acid (EAA) leucine is the most important protein component that plays an important role for muscle protein synthesis and declined proteolysis. Encouraging older adults to intake adequate protein with a high rich-leucine diet such as beef, fish and legumes is advised [35].
Vitamin D decreases with age as a result of intrinsic change in vitamin D synthesis and extrinsic causes eg. malnutrition and reduced sunlight exposure in older adults particularly in frail elderly [43,44]. It is indicated in osteoporosis and vitamin D deficiency but the role for sarcopenia is limited [39]. Vitamin D deficiency is related to altered muscle morphology causing osteomalacia and myopathy, reduced muscle strength, muscle mass and physical performance and bone mineral density that leads to an increased risk of falling and fracture as reported in observational studies and meta-analysis [43]. Vitamin D supplementation; however, does not show beneficial effects in improved muscle strength, muscle function and decreased risk of falls and fracture but co-administration with 1000 mg of calcium in vitamin D deficient patients can decrease this risk of falling [43]. This effect is dose-dependent (700–1000 IU/d of vitamin D3) and vitamin D level of at least 60 nmol/L is required for fall and fracture prevention in community-dwelling older adults [35,43,45–47].
There is evidence that a combination of exercise and adequate dietary supplementation is superior to exercise alone for increased muscle strength, muscle mass and gait speed in sarcopenic patients. Therefore adequate energy and protein intake during exercise is important [48–50].

3. *Medications*: the mechanisms of pharmacological management of sarcopenia focus on various pathways such as androgen receptors, peroxisome proliferator-activiated receptor-gamma coactivator 1-alpha, myostatin, peroxisome proliferator-activated receptor-delta, insulin-like growth factor 1, beta-adrenergic receptors, neuregulins, angiotensin-converting enzyme, and inflammatory cytokines. There is; however, no drug proven for use in sarcopenia for prevention and treatment at present. Some medications improved muscle mass, muscle function and physical performance in animal studies but there are relatively small trials in older adults. The adverse effects of pharmacological use are also the limitations of prescribing these medications. New future drugs that improve functional decline in older adults are of interest. Most studied drugs are testosterone, GH, DHEA and vitamin D [39,51,52].
Testosterone is an anabolic hormone that is currently indicated in persons with androgen deficiency. It can improve muscle mass, reduce fat mass, but the benefit in improvement of muscle strength is insufficient to recommend its use due to the methodological issues. High dose testosterone increased contraction force in older adults. In addition, testosterone is associated with prostate cancer, increased cardiovascular risk, exacerbates sleep apnea, transient fluid retention, gynaecomastia, aggressive behavior, and increased red cell mass which contradicts its use in older adults [37,39,53].
Growth hormone (GH) treatment is indicated in growth disorders and growth hormone deficiency. The benefits of GH in older adults are associated with increased total lean body mass, decreased fat mass and decreased bone demineralized rate but the role in increased muscle strength, muscle power, aerobic endurance and physical performance after short treatment periods is limited. Severe side effects are also found including joint pain, carpal tunnel syndrome, edema, carbohydrate intolerance, diabetes and tumors [39,51,54].
Dehydroepiandrosteron (DHEA) is a precursor of sex hormones and indicated in testosterone deficiency. It can increase bone density in older adults and it is hypothesized that it can increase muscle strength via an increased ratio of circulating testosterone to cortisol. In human studies, the effects in increased muscle mass, muscle strength and muscle function were questionable. Therefore, it cannot be recommended for use in sarcopenic patients [36,39].

7. Future research in Asia

There is growing research regarding sarcopenia in Asia. Most studies have been conducted in East Asia but ethnicities, cultural backgrounds and body sizes can influence the prevalence of sarcopenia. Other parts of Asia are, therefore, encouraged to focus on this area. Studying should be directed

to prevention and treatment of sarcopenia using exercise or dietary programs that are suited to the lifestyles of Asian populations. Early recognition of this new geriatric syndrome is also very crucial for detection and novel studies should pay attention to identifying the associated factors that underlie mechanisms of sarcopenia which can be modified prior to established sarcopenia.

8. Conclusion

Sarcopenia is one of the geriatric syndromes that increases with age and is associated with numerous adverse outcomes. The prevalence of sarcopenia in Asia is diverse due to the differences in its definition and methodological studies. Older adults or high risk persons should be screened for this condition. Exercise especially PRE and adequate nutritional support are the key components of management. To date, an unclear benefit of medications for treatment of sarcopenia is noted. Future study should be straight forward to include intervention for prevention and treatment of sarcopenia.

Conflicts of interest

The authors declared of no conflicts of interest.

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References

[1] Baumgartner RN, Waters DL, Gallagher D, Morley JE, Garry PJ. Predictors of skeletal muscle mass in elderly men and women. Mech Ageing Dev 1999;107:123–36.
[2] Cooper C, Dere W, Evans W, Kanis JA, Rizzoli R, Sayer AA, et al. Frailty and sarcopenia: definitions and outcome parameters. Osteoporos Int 2012;23:1839–48.
[3] Morley JE, Anker SD, von Haehling S. Prevalence, incidence, and clinical impact of sarcopenia: facts, numbers, and epidemiology-update 2014. J Cachexia Sarcopenia Muscle 2014;5:253–9.
[4] Visser M, Schaap LA. Consequences of sarcopenia. Clin Geriatr Med 2011;27:387–99.
[5] Lang T, Streeper T, Cawthon P, Baldwin K, Taaffe DR, Harris TB. Sarcopenia: etiology, clinical consequences, intervention, and assessment. Osteoporos Int 2010;21:543–59.
[6] Rizzoli R, Reginster JY, Arnal JF, Bautmans I, Beaudart C, Bischoff-Ferrari H, et al. Quality of life in sarcopenia and frailty. Calcif Tissue Int 2013;93:101–20.
[7] Rantanen T, Volpato S, Ferrucci L, Heikkinen E, Fried LP, Guralnik JM. Handgrip strength and cause-specific and total mortality in older disabled women: exploring the mechanism. J Am Geriatr Soc 2003;51:636–41.
[8] Janssen I. Influence of sarcopenia on the development of physical disability: the Cardiovascular Health Study. J Am Geriatr Soc 2006;54:56–62.
[9] Lauretani F, Russo CR, Bandinelli S, Bartali B, Cavazzini C, Di Iorio A, et al. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. J Appl Physiol (1985) 2003;95:1851–60.
[10] Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. J Am Geriatr Soc 2002;50:889–96.
[11] Rosenberg IH. Sarcopenia: origins and clinical relevance. J Nutr 1997;127:990S–1S.
[12] Kim TN, Choi KM. Sarcopenia: definition, epidemiology, and pathophysiology. J Bone Metab 2013;20:1–10.
[13] Auyeung TW, Lee SW, Leung J, Kwok T, Woo J. Age-associated decline of muscle mass, grip strength and gait speed: a 4-year longitudinal study of 3018 community-dwelling older Chinese. Geriatr Gerontol Int 2014;14:76–84.
[14] Chen LK, Liu LK, Woo J, Assantachai P, Auyeung TW, Bahyah KS, et al. Sarcopenia in Asia: consensus report of the asian working group for sarcopenia. J Am Med Dir Assoc 2014;15:95–101.
[15] Beaudart C, Rizzoli R, Bruyere O, Reginster JY, Biver E. Sarcopenia: burden and challenges for public health. Arch Public Health 2014;72:45.
[16] Lau EM, Lynn HS, Woo JW, Kwok TC, Melton 3rd LJ. Prevalence of and risk factors for sarcopenia in elderly Chinese men and women. J Gerontol A Biol Sci Med Sci 2005;60:213–6.
[17] Lee JS, Auyeung TW, Kwok T, Lau EM, Leung PC, Woo J. Associated factors and health impact of sarcopenia in older chinese men and women: a cross-sectional study. Gerontology 2007;53:404–10.
[18] Pongchaiyakul C, Limpawattana P, Kotruchin P, Rajatanavin R. Prevalence of sarcopenia and associated factors among Thai population. J Bone Min Metab 2013;31:346–50.
[19] Kim TN, Park MS, Yang SJ, Yoo HJ, Kang HJ, Song W, et al. Prevalence and determinant factors of sarcopenia in patients with type 2 diabetes: the Korean Sarcopenic Obesity Study (KSOS). Diabetes Care 2010;33:1497–9.
[20] Morley JE. Sarcopenia in the elderly. Fam Pract 2012;29:i44–8.
[21] Sanchez-Rodriguez D, Marco E, Miralles R, Fayos M, Mojal S, Alvarado M, et al. Sarcopenia, physical rehabilitation and functional outcomes of patients in a subacute geriatric care unit. Arch Gerontol Geriatr 2014;59:39–43.
[22] Tanimoto Y, Watanabe M, Sun W, Sugiura Y, Hayashida I, Kusabiraki T, et al. Sarcopenia and falls in community-dwelling elderly subjects in Japan: defining sarcopenia according to criteria of the European Working Group on Sarcopenia in older people. Arch Gerontol Geriatr 2014;59:295–9.
[23] Landi F, Cruz-Jentoft AJ, Liperoti R, Russo A, Giovannini S, Tosato M, et al. Sarcopenia and mortality risk in frail older persons aged 80 years and older: results from ilSIRENTE study. Age Ageing 2013;42:203–9.
[24] Han K, Park YM, Kwon HS, Ko SH, Lee SH, Yim HW, et al. Sarcopenia as a determinant of blood pressure in older Koreans: findings from the Korea National Health and Nutrition Examination Surveys (KNHANES) 2008-2010. PLoS One 2014;9:e86902.
[25] Chin SO, Rhee SY, Chon S, Hwang YC, Jeong IK, Oh S, et al. Sarcopenia is independently associated with cardiovascular disease in older Korean adults: the Korea National Health and Nutrition Examination Survey (KNHANES) from 2009. PLoS One 2013;8:e60119.
[26] Sanada K, Miyachi M, Tanimoto M, Yamamoto K, Murakami H, Okumura S, et al. A cross-sectional study of sarcopenia in Japanese men and women: reference values and association with cardiovascular risk factors. Eur J Appl Physiol 2010;110:57–65.
[27] Sanada K, Iemitsu M, Murakami H, Gando Y, Kawano H, Kawakami R, et al. Adverse effects of coexistence of sarcopenia and metabolic syndrome in Japanese women. Eur J Clin Nutr 2012;66:1093–8.
[28] Kim TN, Yang SJ, Yoo HJ, Lim KI, Kang HJ, Song W, et al. Prevalence of sarcopenia and sarcopenic obesity in Korean adults: the Korean sarcopenic obesity study. Int J Obes (Lond) 2009;33:885–92.
[29] Lim S, Kim JH, Yoon JW, Kang SM, Choi SH, Park YJ, et al. Sarcopenic obesity: prevalence and association with metabolic syndrome in the Korean Longitudinal Study on Health and Aging (KLoSHA). Diabetes Care 2010;33:1652–4.
[30] Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in older People. Age Ageing 2010;39:412–23.

[31] Marcell TJ. Sarcopenia: causes, consequences, and preventions. J Gerontol A Biol Sci Med Sci 2003;58:M911−6.
[32] Muscaritoli M, Anker SD, Argiles J, Aversa Z, Bauer JM, Biolo G, et al. Consensus definition of sarcopenia, cachexia and pre-cachexia: joint document elaborated by Special Interest Groups (SIG) "cachexia-anorexia in chronic wasting diseases" and "nutrition in geriatrics". Clin Nutr 2010;29:154−9.
[33] Assantachai P, Muangpaisan W, Intalapaporn S, Sitthichai K, Udompunturak S. Cut-off points of quadriceps strength, declines and relationships of sarcopenia-related variables among Thai community-dwelling older adults. Geriatr Gerontol Int 2014;14:61−8.
[34] Arai H, Akishita M, Chen LK. Growing research on sarcopenia in Asia. Geriatr Gerontol Int 2014;14:1−7.
[35] Rom O, Kaisari S, Aizenbud D, Reznick AZ. Lifestyle and sarcopenia-etiology, prevention, and treatment. Rambam Maimonides Med J 2012;3:e0024.
[36] Borst SE. Interventions for sarcopenia and muscle weakness in older people. Age Ageing 2004;33:548−55.
[37] Wang C, Bai L. Sarcopenia in the elderly: basic and clinical issues. Geriatr Gerontol Int 2012;12:388−96.
[38] Montero-Fernandez N, Serra-Rexach JA. Role of exercise on sarcopenia in the elderly. Eur J Phys Rehabil Med 2013;49:131−43.
[39] Malafarina V, Uriz-Otano F, Iniesta R, Gil-Guerrero L. Sarcopenia in the elderly: diagnosis, physiopathology and treatment. Maturitas 2012;71:109−14.
[40] Liu CJ, Latham N. Can progressive resistance strength training reduce physical disability in older adults? A meta-analysis study. Disabil Rehabil 2011;33:87−97.
[41] Burton LA, Sumukadas D. Optimal management of sarcopenia. Clin Interv Aging 2010;5:217−28.
[42] Peterson MD, Rhea MR, Sen A, Gordon PM. Resistance exercise for muscular strength in older adults: a meta-analysis. Ageing Res Rev 2010;9:226−37.
[43] Anagnostis P, Dimopoulou C, Karras S, Lambrinoudaki I, Goulis DG. Sarcopenia in post-menopausal women: is there any role for vitamin D? Maturitas 2015 Sep;82(1):56−64.
[44] Girgis CM, Baldock PA, Downes M. Vitamin D, muscle and bone: integrating effects in development, aging and injury. Mol Cell Endocrinol 2015;410:3−10.
[45] Halfon M, Phan O, Teta D, Vitamin D. A review on its effects on muscle strength, the risk of fall, and frailty. Biomed Res Int 2015;2015:953241.
[46] Pfeifer M, Begerow B, Minne HW, Suppan K, Fahrleitner-Pammer A, Dobnig H. Effects of a long-term vitamin D and calcium supplementation on falls and parameters of muscle function in community-dwelling older individuals. Osteoporos Int 2009;20:315−22.
[47] Waldron N, Hill AM, Barker A. Falls prevention in older adults - assessment and management. Aust Fam Physician 2012;41:930−5.
[48] Singh MA, Ding W, Manfredi TJ, Solares GS, O'Neill EF, Clements KM, et al. Insulin-like growth factor I in skeletal muscle after weight-lifting exercise in frail elders. Am J Physiol 1999;277:E135−43.
[49] Kim HK, Suzuki T, Saito K, Yoshida H, Kobayashi H, Kato H, et al. Effects of exercise and amino acid supplementation on body composition and physical function in community-dwelling elderly Japanese sarcopenic women: a randomized controlled trial. J Am Geriatr Soc 2012;60:16−23.
[50] Daly RM. Independent and combined effects of exercise and vitamin D on muscle morphology, function and falls in the elderly. Nutrients 2010;2:1005−17.
[51] Papadakis MA, Grady D, Black D, Tierney MJ, Gooding GA, Schambelan M, et al. Growth hormone replacement in healthy older men improves body composition but not functional ability. Ann Intern Med 1996;124:708−16.
[52] Isidori AM, Giannetta E, Greco EA, Gianfrilli D, Bonifacio V, Isidori A, et al. Effects of testosterone on body composition, bone metabolism and serum lipid profile in middle-aged men: a meta-analysis. Clin Endocrinol (Oxf) 2005;63:280−93.
[53] Basualto-Alarcon C, Varela D, Duran J, Maass R, Estrada M. Sarcopenia and androgens: a link between pathology and treatment. Front Endocrinol (Lausanne) 2014;5:217.
[54] Sattler FR. Growth hormone in the aging male. Best Pract Res Clin Endocrinol Metab 2013;27:541−55.